Impact of Changes in Chain Restaurant Calories over Time on Obesity Risk

Sara N. Bleich, PhD[1], Jesse C. Jones-Smith, PhD, MPH[2], Marian P. Jarlenski, PhD, MPH[3], Julia A. Wolfson, PhD, MPP[4], Johannah M. Frelier, MPH[1], Huiru Tao, MSc[1], Yuchen Hu, BSc[1,2,3,4,5,6], Anna Zink, PhD[5], Caroline G. Dunn, PhD, MS[1], Mark J. Soto, MA[1], and Bradley J. Herring, PhD[6]

[1]Department of Health Policy and Management, Harvard T.H. Chan School of Public Health, Boston, MA, USA; [2]Department of Health Services, University of Washington School of Public Health, Seattle, WA, USA; [3]Department of Health Policy and Management, University of Pittsburgh Graduate School of Public Health, Pittsburgh, PA, USA; [4]Department of Health Management and Policy, Department of Nutritional Sciences, University of Michigan School of Public Health, Ann Arbor, MI, USA; [5]Graduate School of Arts and Sciences, Harvard University, Cambridge, MA, USA; [6]Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA.

BACKGROUND: Prior research on the restaurant environment and obesity risk is limited by cross-sectional data and a focus on specific geographic areas.
OBJECTIVE: To measure the impact of changes in chain restaurant calories over time on body mass index (BMI).
DESIGN: We used a first-difference model to examine whether changes from 2012 to 2015 in chain restaurant calories per capita were associated with percent changes in BMI. We also examined differences by race and county income, restaurant type, and initial body weight categories.
SETTING: USA (207 counties across 39 states).
PARTICIPANTS: 447,873 adult patients who visited an athenahealth medical provider in 2012 and 2015 where BMI was measured.
MAIN OUTCOMES MEASURED: Percent change in objectively measured BMI from 2012 to 2015.
RESULTS: Across all patients, changes in chain restaurant calories per capita were not associated with percent changes in BMI. For Black or Hispanic adults, a 10% increase in exposure to chain restaurant calories per capita was associated with a 0.16 percentage-point increase in BMI (95% CI 0.03, 0.30). This translates into a predicted weight increase of 0.89 pounds (or a 0.53% BMI increase) for an average weight woman at the 90th percentile of increases in the restaurant environment from 2012 to 2015 versus an increase 0.39 pounds (or 0.23% BMI increase) at the 10th percentile. Greater increases in exposure to chain restaurant calories also significantly increased BMI for Black or Hispanic adults receiving healthcare services in lower-income counties (0.26, 95% CI 0.04, 0.49) and with overweight/obesity (0.16, 95% CI 0.04, 0.29).
LIMITATIONS: Generalizability to non-chain restaurants is unknown and the sample of athenahealth patients is relatively homogenous.
CONCLUSIONS: Increased exposure to chain restaurant calories per capita was associated with increased weight gain among Black or Hispanic adults.

KEY WORDS: restaurant calories; obesity risk; longitudinal; vulnerable populations.

J Gen Intern Med 35(6):1743–50
DOI: 10.1007/s11606-020-05683-8

Prior Presentations *This research was presented at the Robert Wood Johnson Foundation Health Eating Research conference in April 2018 and at The Obesity Society in November 2018.*

Electronic supplementary material *The online version of this article (https://doi.org/10.1007/s11606-020-05683-8) contains supplementary material, which is available to authorized users.*

Received August 14, 2019
Accepted January 26, 2020
Published online February 14, 2020

INTRODUCTION

Obesity is a significant public health problem. It is prevalent, of consequence, a substantial contributor to healthcare costs, and disproportionately present among racial and ethnic minority populations.[1–4] Evidence suggests that the food environment (defined as the availability of food for purchase at stores such as supermarkets, food service establishments such as restaurants) is associated with obesity risk, though the nature of this relationship has not been fully described.[5, 6] Restaurants are one key element of the food environment, where sales have increased over 5 decades.[7] In 2018, Americans spent $825 billion in over 1 million restaurants across the USA.[8, 9] Meals consumed at restaurants tend to be characterized by large portion sizes[10] and high levels of calories and fat.[11]

Research on the associations between the food environment and obesity[12] remains largely cross-sectional (which limits the identification of causal relationships),[13–15] almost exclusively investigates neighborhood food environments (which limits findings because people often travel outside their residential neighborhood),[16–20] and often focuses on specific cities or regional areas (which limits generalizability).[13–15] Another major limitation of past studies is that they only measure the number and/or density of restaurants without incorporating variation in caloric content of menu items offered by restaurant chains that are changing over time.[21–29] Failure to account for calories of menu items may mask potential associations between the restaurant environment and obesity.

To address these knowledge gaps, we combined three data sources for 2012 and 2015 which allow—for the first time—a county-level assessment of changes over time in chain restaurant calories per capita and the impact on body mass index (BMI, kg/m^2), overall and among race/ethnicity and income categories. We also examined differences by restaurant type (fast food, fast causal, full service, using existing definitions[27]) and baseline body weight status (healthy weight, overweight/obese). We expected that greater increases in exposure to the restaurant environment would be associated with higher BMI and obesity risk, particularly for low-income and racial/ethnic minority populations.

METHODS

We examined individual-level models with the percent change in BMI over time as the outcome and changes in county-level chain restaurant calories per capita over time as the primary independent variable of interest. We compiled data from several sources identified below (and detailed in Appendix A in the ESM). This study was determined to be non-human subjects research by the Institutional Review Board of the Harvard Chan School of Public Health.

Sample

We studied a sample of adults from athenahealth, a healthcare technology and services company which connects more than 85,000 medical providers (mostly outpatient care settings from primary care visits). De-identified patient data from 2012 to 2016 were obtained from athenahealth's ambulatory electronic health record (EHR) in which a unique randomized identifier was used to track patients over time.[30] Participant data included the county where services were rendered, race/ethnicity, gender, age, BMI, and date of each visit. We focused our analysis on the subset of adults (ages 20 and older) with measures of BMI for both 2012 and 2015 to focus on examining changes in BMI over time.

While we had access to data for 10,809,725 patients who visited an athenahealth medical provider at least once between 2012 and 2016, our final analytic sample included 447,873 adult patients with measured BMI values for 2012 and 2015 who were assigned to 207 unique counties across 39 states, which included 9 of the 10 most populous US cities (Fig. 1; see Appendix B in the ESM for more details about the exclusions).[7] Our sample is similar to the USA overall, but has a larger share of patients that are female, White, over 60, and covered by Medicare (Appendix B in the ESM).]–>

Measures

Change in BMI. The primary outcome was the patient's percent change in BMI from 2012 to 2015. The height and weight data in the athenahealth EHR are measured values. We calculated average annual BMI values for each patient in 2012 and 2015 as the mean of the BMI estimates from the provider visits for each year's four quarters. For any quarter in which the patient did not visit a provider, we imputed the BMI value based on adjacent quarters (see Appendix C in the ESM for details). We then calculated each patient's percent change in BMI from 2012 to 2015.

Change in Chain Restaurant Calories per Capita. The independent variable of interest is a county-level measure of changes in chain restaurant calories per capita from 2012 to 2015. Our measure of chain restaurant calories per capita combines mean calories for items offered on chain restaurant menus (assigned to each chain), the number of chain restaurant store locations, and county population. Three data sources were used to create this measure of the restaurant environment (Appendix A in the ESM): (1) MenuStat,[31] which provides annual data on the caloric content of menu items for each of the 66 of the largest US chain restaurants starting in 2012 (covering about 28,000 items), (2) AggData (www.aggdata.com), which provides the zip code locations for these 66 different restaurant chains in each year, and (3) the US Census Bureau's American Community Survey, which provides data on county population. Details about the restaurant exposure measure calculation, along with an example for how we calculated chain restaurant calories per capita for a single county, can be found in Appendix D in the ESM.

Figure 2 depicts the changes in this restaurant environment measure of calories per capita between 2012 and 2015 for all counties assigned to our final sample of athenahealth patients. The baseline restaurant exposure measure has been normalized to equal 10 for 2012 to ease the subsequent interpretation of the magnitude of the results. The change in the exposure measure from 2012 to 2015 at the 90th percentile across counties was equivalent to a 15% increase (i.e., an increase of 1.5 relative to a mean value normalized to 10), while the change in the exposure measure at the 10th percentile across counties was equivalent to a 3% decrease (i.e., a decrease of 0.3). In 2012, 74% of the total calorie per capita measure was attributed to fast food restaurants, 9% to fast casual restaurants, and 17% to full service establishments.]–>

Covariates. Individual-level demographics were self-reported by patients in the athenahealth data. Age was categorized in 10-year intervals beginning at 20 years old by athenahealth, and patients 60 years old and older were consolidated to one category. Participants reported their primary race/ethnicity into one of the following mutually exclusive categories: White, Black/African American, Hispanic/Latino/Spanish, or Asian; we pooled Black and Hispanic participants due to the small sample size of the latter. Insurance type was either commercial, Medicaid, Medicare, self-pay or other.

County-level sociodemographic factors for years 2012 and 2015 included unemployment rates (representing the percentage of unemployed individuals over the age of 16 as a

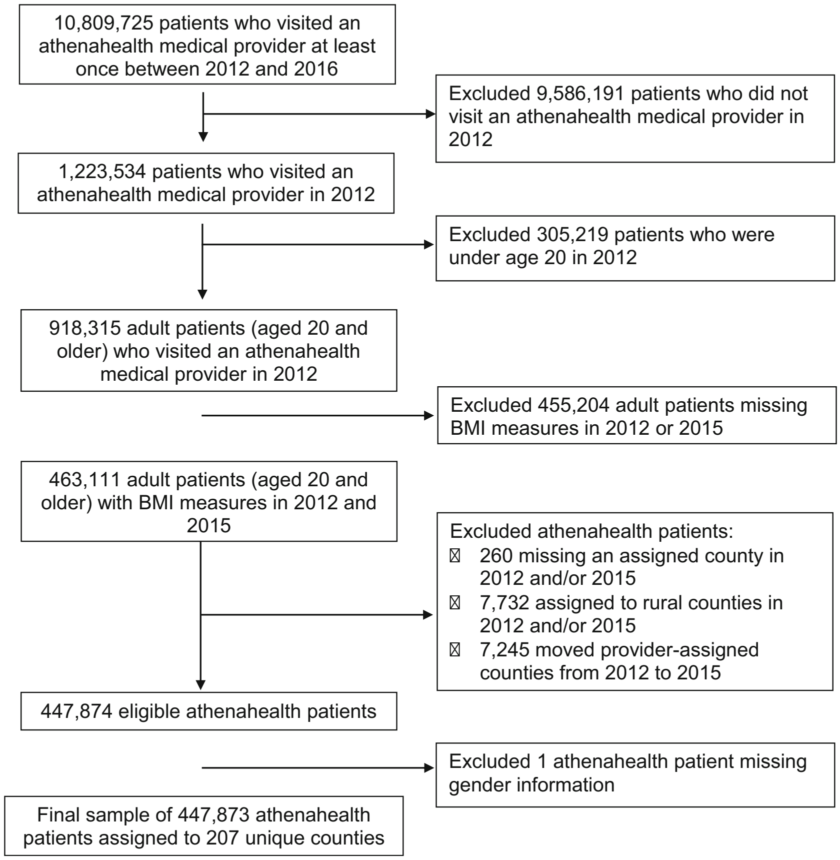

Figure 1 athenahealth sample selection 10,809,725 patients who visited an athenahealth medical provider at least once between 2012 and 2016. Note: No athenahealth patients in the final sample were excluded for an implausible BMI at baseline or a change in BMI from 2012 to 2015 of > 50%. All counties in the final sample had a non-zero restaurant exposure in both 2012 and 2015.

percentage of the county's workforce), median household income, and education attainment (measured as the percent of county residents with 4 or more years of college). The county-level sociodemographic measures included in the model are the changes from 2012 to 2015.

Statistical Analysis

We used a person-level first-difference approach, which reduces bias from potential unmeasured confounders by considering effects of changes in exposures on changes in outcomes, thus differencing out time-invariant unmeasured confounders. We employed linear regression models with the percent change in BMI as the dependent variable, the change in exposure to the restaurant environment as the primary independent variable, and the set of baseline individual-level demographics and changes in county-level socio-demographics as covariates; the latter help control for trends that may be related to both changes in chain restaurant calories per capita and changes in BMI over time. All analyses were conducted in 2019 with Stata Version 15 (StatCorp LLC, College Station, TX).[32] The robust estimator of variance was used to correct standard errors, and the estimator was adjusted for non-independence of individual observations within counties using the cluster command.

We normalized the restaurant exposure measure for 2012 to have an average equal to 10, so that a one-unit change over time from 2012 to 2015 would be consistent with a 10% increase in the average baseline restaurant exposure. As a result, the coefficient in the regression can be interpreted as the percentage-point change in BMI associated with a 10% increase in restaurant exposure over time. To further assist with the interpretation of our results, we also present predicted percent changes in BMI associated with two points in the distribution of changes in the restaurant environment over time—specifically change in restaurant exposure at the 10th and 90th percentiles. It combines the coefficients from the first-difference model with the descriptive statistics from the sample for the outcome and primary independent variable of interest. Additionally, we translate those predicted percent changes in BMI to changes in pounds, where we assume the height (63.7 inches) and weight (168.5 pounds) for an average woman.[33]

In addition to examining results for the entire sample, we also examined the following: (1) potential disparities across subsamples stratified by patient-level race/ethnicity and county-level income (using the median value in county-level median household incomes across our sample of patients to determine the cutoff for lower-income versus higher-income counties); (2) alternative measures

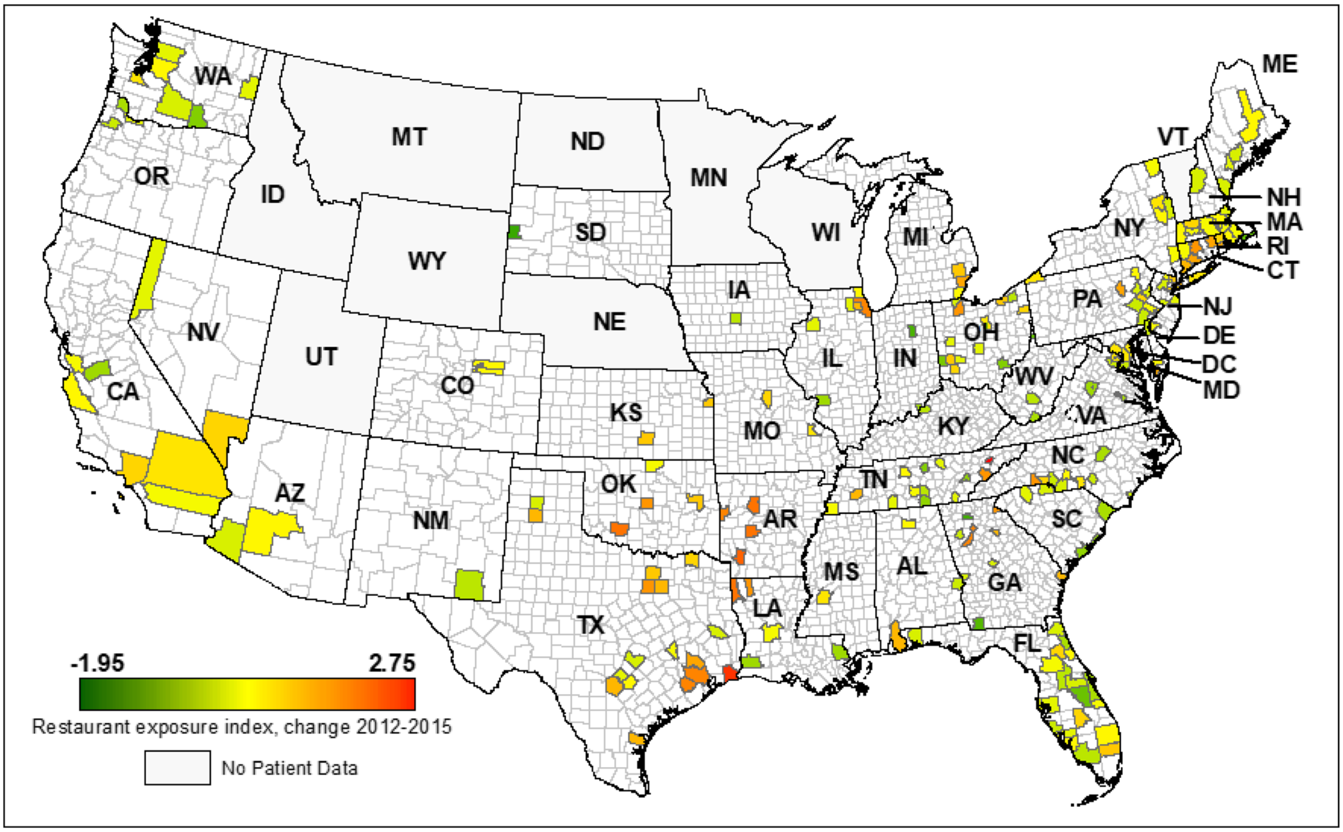

Figure 2 Change in restaurant exposure, 2012 to 2015. Notes: The athenahealth sample encompasses 9 of the 10 most populous cities (New York, NY, Los Angeles, CA, Chicago, IL, Houston, TX, Phoenix, AZ, Philadelphia, PA, San Antonio, TX, Dallas, TX, and San Jose, CA). No data are available for San Diego, CA, 39 out of the 50 states, and 207 out of the 3007 counties in the USA. The total population in these 39 athenahealth states represents 89% of the total population in the USA in 2012, and the total population in these 207 athenahealth counties represents 37% of the total population in the USA in 2012. During this time period, no data were available for patients receiving care in Alaska, Hawaii, Idaho, Minnesota, Montana, Nebraska, North Dakota, Utah, Vermont, Wisconsin, Wyoming, or the District of Columbia. County-level restaurant exposure was normalized to equal an average of 10 for 2012. This then implies that a one-unit change in the normalized restaurant environment is consistent with a 10% change in the restaurant environment.

of chain restaurant calories per capita based on the different types of restaurants: fast food, fast casual, and full service,[34, 35] (also stratified by race and income); and (3) a subset of people based on their baseline weight status (healthy weight versus overweight/obese) in 2012, because response to changes in chain restaurant calories per capita may differ by BMI (again, stratified by race and income).[25] Statistical significance was assessed at the traditional $p < 0.05$. All significant results remain after adjustment for multiple comparisons using the Benjamini-Hochberg procedure with a 0.15 false discovery rate unless noted otherwise (see Appendix E in the ESM).[36] Results from models that instead include interactions between restaurant calories per capita, race/ethnicity, and income (rather than examining stratified samples by race/ethnicity and income) can be found in Appendix F in the ESM.

Role of the Funding Source

This study was supported by Health Data for Action, a program of the Robert Wood Johnson Foundation Health. The funder played no role in the research.

RESULTS

The characteristics for the study sample are in Table 1. The final sample of athenahealth patients ($n = 447{,}873$) had an average measured BMI of 29.8 in 2012 and an average increase of 0.08 points up to 29.9 in 2015, corresponding to an average percent change in BMI of 0.55%. However, there was considerable variation across people in their percent change in BMI from 2012 to 2015 (not illustrated in this table's average change over time), with a 7.92% decrease at the 10th percentile and an 8.96% increase at the 90th percentile. In addition, the sample was primarily older (42% were 60+ years), female (57%), White (75%), and commercially insured (57%). On average, they received healthcare services in counties where 29% of residents had completed 4 or more years of college, the unemployment rate was 8%, and the median household income was $52,724.

The results of the first-difference model analyzing the association between changes in chain restaurant calories per capita and percent changes in BMI, both overall and by individual-level race/ethnicity and county-level income, are in Table 2. Overall, there was no association between changes in chain restaurant calories per capita and percent changes in

Table 1 Baseline Individual- and County-Level Characteristics in 2012

Individual patient characteristics	
Final sample of athenahealth patients	447,873
Average BMI (kg/m^2), overall and by race/ethnicity	
Overall	29.8 (+ 0.08 in 2015)
White	29.7 (+ 0.08 in 2015)
Black or Hispanic	32.0 (+ 0.04 in 2015)
Asian	25.9 (+ 0.18 in 2015)
Age group	*N* (%)
60+	187,006 (42%)
50–59	103,228 (23%)
40–49	78,141 (17%)
30–39	48,204 (11%)
20–29	31,294 (7%)
Gender	*N* (%)
Female	255,000 (57%)
Male	192,873 (43%)
Race/ethnicity	*N (%)*
White	337,608 (75%)
Black or Hispanic	40,759 (9%)
Asian	7908 (2%)
Other or declined	61,598 (14%)
Insurance type	*N* (%)
Commercial	256,375 (57%)
Medicare	148,991 (33%)
Medicaid	26,088 (6%)
Self-pay	14,693 (3%)
Other	1726 (0.4%)
County characteristics	
Percent with 4+ years of college	28.5% (+ 1.3% in 2015)
Unemployment rate	8.1% (− 2.6% in 2015)
Median household income	$52,724 (+ $4327 in 2015)

Notes: Patient-level data are from athenahealth. County-level attributes were obtained from Bureau of Labor Statistics, US Census Bureau, and Health Resources and Services Administration

BMI; the point estimate is a 0.02 percentage-point increase in the change in BMI (95% CI − 0.06, 0.11) associated with a 10% increase in the restaurant exposure measure. Likewise, there was no association when stratified by county income. However, for Black or Hispanic adults, there was a positive and significant association between chain restaurant calories per capita and BMI; specifically, a 0.16 percentage-point increase in BMI from 2012 to 2015 (95% CI 0.03, 0.30, $p =$ 0.019) was associated with a 10% increase in the restaurant exposure measure. These results remain statistically significant after adjusting for multiple comparisons using the Benjamini-Hochberg procedure.[36] In models where we instead included an interaction between race/ethnicity, income and restaurant exposure, we observed a significantly larger positive association between chain restaurant calories and BMI for Black or Hispanic patients receiving care in lower-income counties; a 10% increase in the average chain restaurant calories per capita is associated with a 0.26 percentage-point higher increase in the change in BMI from 2012 to 2015 (95% CI 0.04, 0.49, $p = 0.023$).

Figure 3 illustrates the magnitude of this observed association between the change in chain restaurant calories per capita and the percent change in BMI for a Black or Hispanic female at three different points in the distribution of change in chain restaurant calories. At the median level of change in chain restaurant calories per capita, there was a 0.36% increase in BMI from 2012 to 2015, corresponding to an increase of 0.61 pounds for typical woman. In counties at the 10th percentile of the change in chain restaurant calories per capita (2% decrease from 2012 to 2015), our model predicts a 0.23% increase in BMI, or 0.39 pounds. In counties at the 90th percentile of change in chain restaurant calories per capita (8% increase from 2012 to 2015), our model predicts a 0.53% increase in BMI, or an increase of 0.89 pounds. Thus, we would expect a difference in 0.50 pounds (i.e., 0.89–0.39) between locations facing lowest versus highest growth in exposure to the restaurant calorie environment.]–>

When examining separate measures of restaurant exposure for each restaurant type independently (fast food, fast casual, full service), no differences were observed by race/ethnicity or county income (Appendix F in the ESM). When stratifying by

Table 2 Association Between Change in Restaurant Exposure and Percent Change in BMI Using First-Difference Models, 2012 to 2015, by Income and Race/Ethnicity

	Overall	White	Black or Hispanic	Asian
All counties				
N	447,873	337,608	40,759	7908
Estimate (95% CI)	0.02 (− 0.06, 0.11)	0.01 (− 0.07, 0.10)	*0.16* (0.03, 0.30)	0.03 (− 0.15, 0.22)
p value	$p = 0.596$	$p = 0.778$	$p = 0.019$	$p = 0.713$
Lower-income counties				
N	211,964	161,185	23,110	2257
Estimate (95% CI)	0.03 (− 0.10, 0.16)	0.02 (− 0.11, 0.15)	*0.26* (0.04, 0.49)	0.35 (− 0.07, 0.78)
p value	$p = 0.641$	$p = 0.769$	$p = 0.023$	$p = 0.103$
Higher-income counties				
N	235,909	176,423	17,649	5651
Estimate (95% CI)	0.04 (− 0.09, 0.17)	0.06 (− 0.08, 0.20)	0.06 (− 0.19, 0.30)	− 0.09 (− 0.35, 0.17)
p value	$p = 0.534$	$p = 0.395$	$p = 0.639$	$p = 0.510$

Notes: These coefficients can be interpreted as the percentage-point change in BMI associated with a 10% increase in the average restaurant exposure measure from 2012 to 2015

Italicized values indicate significance at the $p < 0.05$ level; when we use the Benjamini-Hochberg procedure with a 0.15 false discovery rate to account for multiple comparisons, the significant results remain significant

Lower-income is defined as below the median for county-level median household income for our analytical sample in 2012 (based on the county of the provider instead of the patient's residence); this is at or below $50,706. Higher-income is defined as above the median for county-level median household income for our analytical sample in 2012 (based on the county of the provider instead of the patient's residence); this is above $50,706

All models adjust for individual-level demographics (age, race/ethnicity, insurance type) and changes in county-level socio-demographics (unemployment rate, median household income, education attainment) as covariates

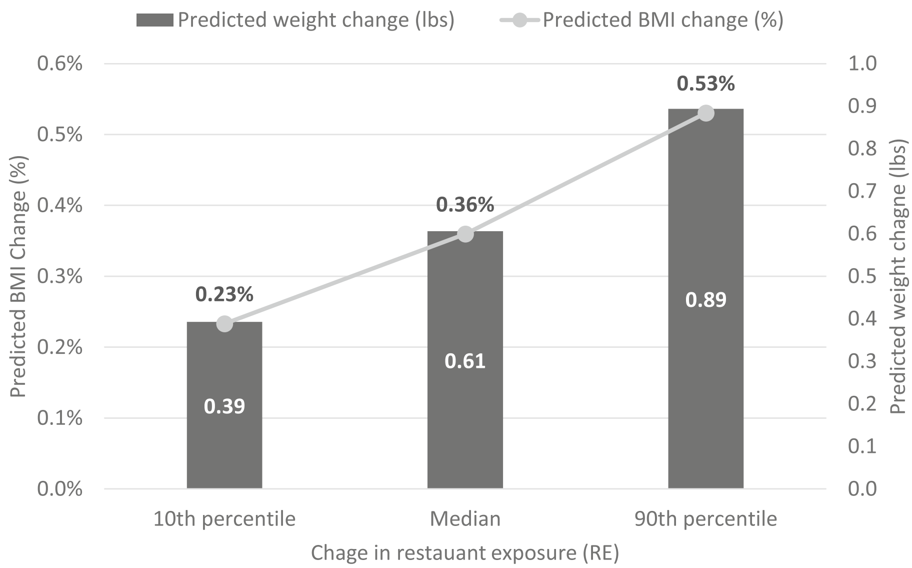

Figure 3 Changes in BMI and weight associated with small and large changes in restaurant exposure for Black or Hispanic adults. Notes: This figure shows three specific predicted values in the percent change in BMI (on the left-side axis) based on the regression result shown in Table 2's model for Black or Hispanic adults adjusted for individual-level demographics (age, race/ethnicity, insurance type) and changes in county-level socio-demographics (unemployment rate, median household income, and education attainment as covariates). The sample size for this subgroup is 40,759. The first column shows the predicted value corresponding to the 10th percentile in change in the restaurant environment, the second column shows the predicted value corresponding to the median change in the restaurant environment, and the third column shows the predicted value corresponding to the 90th percentile in the change in the restaurant environment. The right-side axis then shows the change in pounds corresponding to the change in BMI for an average height/weight woman.

baseline weight status, we only observed a significant association between chain restaurant calories per capita and BMI for initially overweight/obese Black or Hispanic adults (0.16, 95% CI 0.04, 0.29) and initially overweight/obese Black or Hispanic receiving healthcare services in lower-income counties (0.27, 95% CI 0.05, 0.49).

DISCUSSION

This is the first study to use national-level data with objectively measured BMI, to examine whether county-level changes to chain restaurant calories per capita are associated with population weight gain. We observed considerable variation in changes to the restaurant calorie environment across the USA. Using this variation, we found that while increased exposure to chain restaurant calories over time was not associated with changes in adult BMI overall, it was associated with an increase in BMI among Black or Hispanic adults. For a Black or Hispanic woman of average height and weight receiving care in county at the 90th percentile of change in restaurant exposure, this translates into an additional 0.50-pound weight increase over the study period compared with her counterpart in a county at the 10th percentile of change in restaurant exposure. It also appears that increases in BMI among Black or Hispanic adults may be driven by those receiving healthcare in lower-income counties. Moreover, increases in exposure to chain restaurant calories per capita was associated with larger percent changes in BMI for overweight/obese Black or Hispanic adults, driven by those receiving healthcare services in lower-income counties.

While there is a considerable body of research focused on the association between the restaurant environment and obesity risk,[12] our results are most relevant to the smaller subset of longitudinal studies which—importantly—have the ability to control for neighborhood self-selection. Our finding of a null effect for the relationship between exposure chain restaurant calories per capita and BMI for groups other than Black or Hispanic adults differs from earlier studies.[37–39]

There are several reasons why our conclusions may differ from previous longitudinal studies. One could be the saturation of fast food restaurants in the restaurant environment and relatively small changes to this exposure over the study period. A second might be that our study used measured BMI while several prior studies have relied on self-report.[38, 40, 41] A third might be that our measure of the restaurant environment included calories per capita (while still accounting for restaurant density). Prior studies have largely focused on a singular measure such as of food outlet proximity,[37, 40, 41] density,[38, 39, 42] or food price.[41]

Our finding that higher chain restaurant calories per capita was associated with increased BMI for Black or Hispanic adults (overall, those receiving healthcare services in lower-income counties, and those with overweight/obesity) may be related to their relatively higher fast food consumption which has been documented among this group.[43] In addition, a number of studies have documented a positive association between fast food consumption and daily intake (of calories, fat, and sugar),[44–47] and prior studies suggest that the density of fast food restaurants is greater in predominantly Black neighborhoods,[48] although we did not observe differences by restaurant type for Black or Hispanic adults.

The magnitude of effect (i.e., a difference of 0.50 lbs) between those facing a change in the restaurant environment at the 90th percentile instead of the 10th percentile may be considered small but reasonable given our exposure measure and our study design. The average American gains approximately 1.1–2.2 pounds (0.5–1.0 kg) per year. Previous comparative effectiveness research on weight gain prevention has suggested that a difference between groups of 0.5 kg (1.1 lbs) would be considered meaningful.[49] Although the magnitude of effect in this study is less than this threshold, it reflects the population average effect, combining people who eat at restaurants and those who do not. Therefore, our observed magnitude is likely lower than if we were able to determine who among our sample frequented these types of restaurants. These results suggest that healthcare providers interested in helping patients prevent weight gain should encourage less eating away from home. The results also suggest that state and local policymakers might consider policies that reduce exposure to chain restaurants (such a zoning regulations which limit the number of chain restaurants).

More research is needed to more fully characterize longitudinal changes in chain restaurant calories per capita and how those changes might be associated with demographic characteristics such as age, race/ethnicity, and income. Additionally, future research should assess how the associations observed in this analysis are attenuated by marketing, which has been shown to considerably influence consumer behavior[50, 51] and may be disparately targeted at lower-income and racial/ethnic minority populations.[52–54]

Our study has a number of limitations. First, our restaurant sample is limited to 66 large US chain restaurants with available nutrition information. Therefore, these results may not generalize to other restaurant types (e.g., fine-dining restaurants). Second, our measure of chain restaurant calories per capita does not take into account the relative popularity or sales for each item. Information on customer sales or consumption is unknowable from our data. Third, while the sample of people included in this analysis represents a large number followed over several years, the sample disproportionally reflects people with more frequent medical provider visits and is relatively homogeneous with a small representation of non-Whites (25%) and younger adults (18% under 40 years old). While our data come from 39 states which included 9 of the 10 most populous US cities, we only have data from 207 counties which also reduces generalizability. Fourth, if we test for multiple comparisons, the results of our sub-analyses are no longer significant (though the main analyses remain significant). Finally, county of residence, income, and education were not available for athenahealth patients. Therefore, counties were assigned based on where medical services were rendered (which may not be the county of residence) and income and education were assigned to the individual based on this assigned county.

Major strengths of this study include the use of several high-quality datasets[30, 31, 55, 56] and a longitudinal design to provide a dynamic assessment of the food environment over time. To our knowledge, this is the first study to examine changing restaurant exposure as a measure of both restaurant density and caloric content.

CONCLUSION

Exposure to chain restaurant calories per capita is increasing over time, with wide geographic variation across counties. Increased exposure to the restaurant environment was associated with increased BMI for Black or Hispanic adults. Targeted policy and environmental interventions which aim to improve the healthfulness of the restaurant environment may help to attenuate this risk between exposure to the restaurant environment and obesity risk.

Corresponding Author: *Sara N. Bleich, PhD; Department of Health Policy and Management Harvard T.H. Chan School of Public Health, Boston, MA, USA (e-mail: sbleich@hsph.harvard.edu).*

Funding Information *This study was supported by Health Data for Action, a program of the Robert Wood Johnson Foundation.*

Compliance with Ethical Standards:

Conflict of Interest: *No authors have potential conflicts of interest to disclose.*

Disclaimer: *The funder played no role in the research.*

Publisher's Note: *Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.*

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